Target tracking in kilovoltage images using templates of fiducial constellations

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INTRODUCTION

- Accurate tracking of implanted fiducial markers during treatment can provide critical tumour motion information for adaptive radiotherapy [1].
- Identification of markers on kV images acquired during treatment can be challenging due to: (a) image quality, (b) marker location/size or (c) obstructions from other radio-opaque objects in the FoV [2].

AIM

- To develop and analyse a novel method to track implanted radio-opaque fiducial markers in kV images and extract the 6 degrees of freedom motion associated with the tumor target.

METHOD

- CBCT projection images are used to extract a template of fiducial constellations at regular projection intervals
- A template matching approach is used to identify the centroid position of the constellation on the kV images.
- The centroid position of each individual fiducial is extracted using the template and a probability density map about the most likely position of each fiducial relative to the constellation.
- 6-DoF motion is acquired using an inter-dimensional correlation framework [3].

RESULTS

- Tested on two pancreatic SABR patients (two fractions each) in the Ethics approved SPAN-C Trial.
- Figure 1 shows the pre-processing followed to generate the template of the fiducial constellation using the CBCT projections .
- Figure 2 shows the determination of a constellation for a given projection angle on the kV images . The centroid of each individual marker was identified using a template and a probability density map (the dashed ellipses around each marker in Figure 2 represent the 1 standard deviation from the most likely position).
- On the bottom right of Figure 2 the two constellations (kV-based with green and CBCT-based with red) are superimposed indicating a non-rigid deformation between the two estimated constellations.
- Figure 3 shows the calculation of DoF motion based on the estimated position of each marker using an inter-dimension correlation framework.

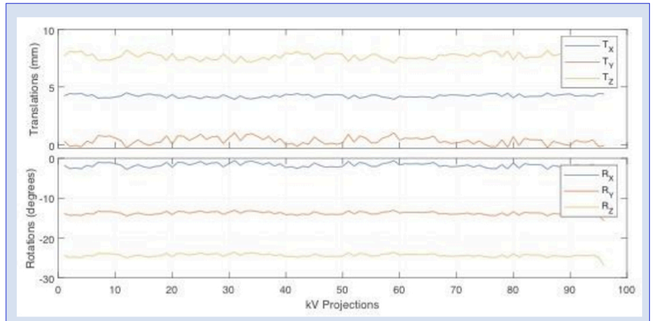

***Figure 3**. Estimated 6 DoF motion from kV images during treatment of a pancreatic cancer patient. Images were acquired during end-exhale. Three translations (top) and three rotations (bottom) are shown as a function of kV projection angle.*

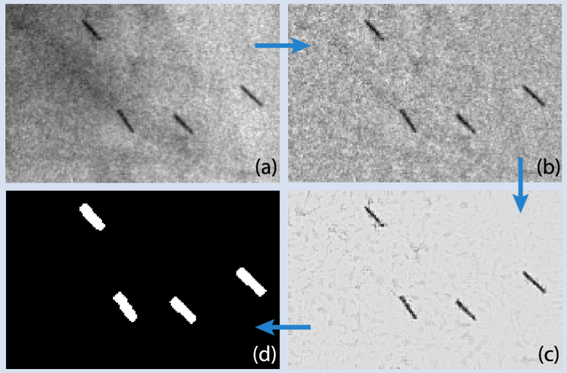

***Figure 1**. Generation of fiducial constellation at a given projection angle, based on the CBCT images before treatment: (a) original projection image cropped around the area of the constellation using the structure set information, (b) background corrected image using a 5th order polynomial fit, (c) after the application of a 9x9 median filter to enhance the contrast of the fiducials and (d) the final segmented fiducial constellation.*

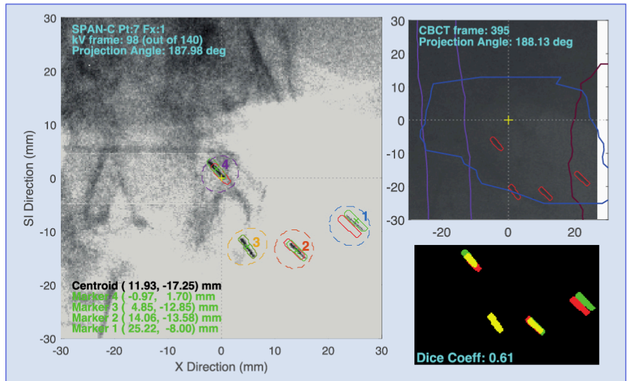

***Figure 2**. Snapshot of the main graphical user interface showing for a given projection angle: (left) fiducial tracking on a kV image acquired during treatment and (top right) the constellation template extracted from the CBCT acquisition before treatment. (Bottom right) Overlapping CBCT (red) and kV (green) constellations, where overlapping regions are shown in yellow. Due to non-rigid deformations during treatment the shape of the extracted CBCT template is not always preserved.*

CONCLUSIONS

- We have developed an automated methodology based on template matching of fiducial constellations on kV images to provide real-time tumor tracking during radiotherapy of pancreatic cancer.
- Preliminary results on two pancreatic patients indicate that this tool can provide an efficient real-time target tracking approach during radiotherapy.
- The proposed method appears to be robust to inter- and intra-fraction deformations.
- The proposed methodology is the first step towards a more generalised framework of automated tracking of other internal landmarks (e.g spine) without the use of implanted fiducials.

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